

RESTRICTED CIRCULATION

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AGRICULTURAL MEMORANDUM NO 958

RADIATION LOSSES DUE TO SHELTER BELTS AND PROTECTIVE SCREENS S.N. WASS

INTRODUCTION

Although most growers recognise the benefits of shelter for reducing both damage and fuel consumption in a glasshouse, many are reluctant to erect any because of possible light losses. This memorandum attempts to quantify radiation losses from shelter belts and insulating cladding. A computer program has been written to calculate these losses.

GLOBAL RADIATION

Global radiation follows a sinusoidal distribution throughout the day with the instantaneous irradiance, I_t (Wm^{-2}), at time t (s) from sunrise being given by -

$$I_t = (R\pi/2h) \sin(\pi t/h) \dots\dots\dots 1$$

where R = daily insolation (MJ m^{-2})
 h = daylength (s)

Thus from average values of R (Smith) we can estimate mid-hour values of irradiance.

PARTITION OF RADIATION

Figure 1 has been drawn from average values of radiation data (Anon) from which it can be seen that the proportion of diffuse radiation follows a similar pattern throughout the year with maxima of 100% at sunrise and sunset and a minimum around noon. Minimum percentage diffuse radiation has been calculated for 9 stations in the UK and monthly values are shown in Appendix 1.

If we assume that the distribution of diffuse radiation is symmetrical about midday, then by standardising the components in figure 1 such that:-

$$x = 100 \left| (t - 12)/d \right| \quad \text{where } t = \text{time (hours)} \\ d = \text{daylength (hours)}$$

$$\text{and } Y = 100 (Id_p - Im_p)/(100 - Im_p) \dots\dots\dots 2$$

where Id_p = percentage diffuse radiation.

Im_p = minimum percentage diffuse radiation.

Then by best fit techniques the following relationship was derived

$$Y = e^z - C \dots\dots\dots 3$$

where $z = 0.0964 X - 0.1002$

and C is a correction term to be applied when $|X - 35| > 0$

and $C = 0.706 |X - 35| - 0.02$

Thus by evaluating equation 3 for any hour we have an estimate of the fractional diffuse radiation and hence the contribution of the direct beam. The accuracy of this method is demonstrated in figure 2.

RADIATION LOSSES

a. DIRECT

From the equation of time we can calculate the length and direction of a shadow for any time and location. If a point is within the shadow cast by an optically opaque screen, then radiation from the direct beam is unavailable. An amount proportional to the optical porosity is assumed to penetrate.

b. DIFFUSE

By assuming that diffuse radiation is homogenous about the celestial ^{done}~~done~~ it can be shown (Sparks) that the percentage loss is given by

$$(1 - P) (1 - 1/\sqrt{1 + a^2})$$

where P = fractional permeability of screen.

a = h/d

h = height of screen

d = distance from screen

Loss of diffuse light for 4 different porosities is shown in Figure 3.

RESULTS

A Fortran program has been written to estimate hourly radiation levels from mean daily values, to partition them into direct and diffuse components, calculate the losses of each at fixed distances from a screen of any orientation and then sum them to give hourly and daily total losses. Figure 4, showing the percentage losses at distances from impermeable shelter belts was constructed from such data.

By combining the diffuse losses from screens at right angles and adding in the loss if either screen puts a point in shadow it is possible to estimate losses over an area with all-round shelter. For example, Figure 5 shows the loss AT GROUND LEVEL over a 1 ha block of glass from an optically opaque shelter belt 4 m high. The shelter is 4H from the east and west walls, 3H from the north wall and 6H from the south wall to give an optimum pattern of losses generally less than 2%. This compares with current recommendations of having shelter 8H from all walls. The average reduction over the whole house is about 0.8%.

A similar diagram can be used to show the effect of insulating cladding which reduces light transmission by about 50%. If we take the shelter belt to represent the glasshouse walls in Figure 5, then for 2 m high cladding on the east and west walls there will be a 5% reduction 3 m in and less than 1% 12 m in. On the north wall reductions will be less than 5% from 3 m in and less than 1% beyond 8 m. However, reductions greater than 5% extend to 13 m from the south wall with the 1% level about 20 m away. With light levels tending to be higher on the outside walls some of these reductions are less serious but it can be seen that the greatest reductions arise through cladding the south wall.

REFERENCES

- ANON Solar Radiation Data for the United Kingdom 1951-75
Met. 0.912.
- Smith, L.P. The Agricultural Climate of England and Wales. MAFF Technical Bulletin 35.
- Sparks, W.R. The Reduction of Diffused Light by a Shelter Belt or Screen.
Agricultural Memorandum No 847. Obtainable from Meteorological Office,
London Road, Bracknell, Berks.

Figure 1

PROPORTION OF DIFFUSE RADIATION

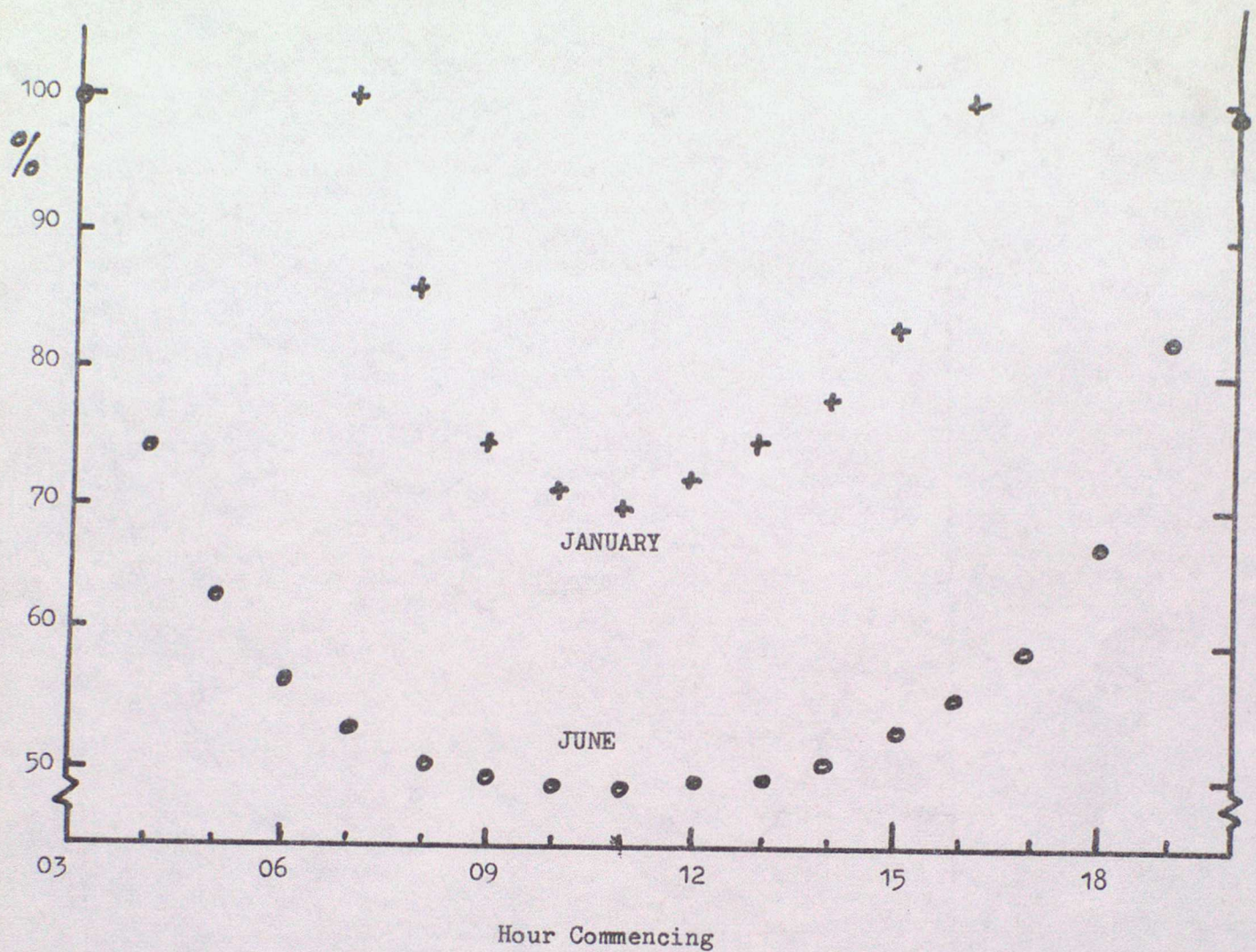


Figure 2

RELATIONSHIP BETWEEN PROPORTION
OF DIFFUSE RADIATION AND TIME

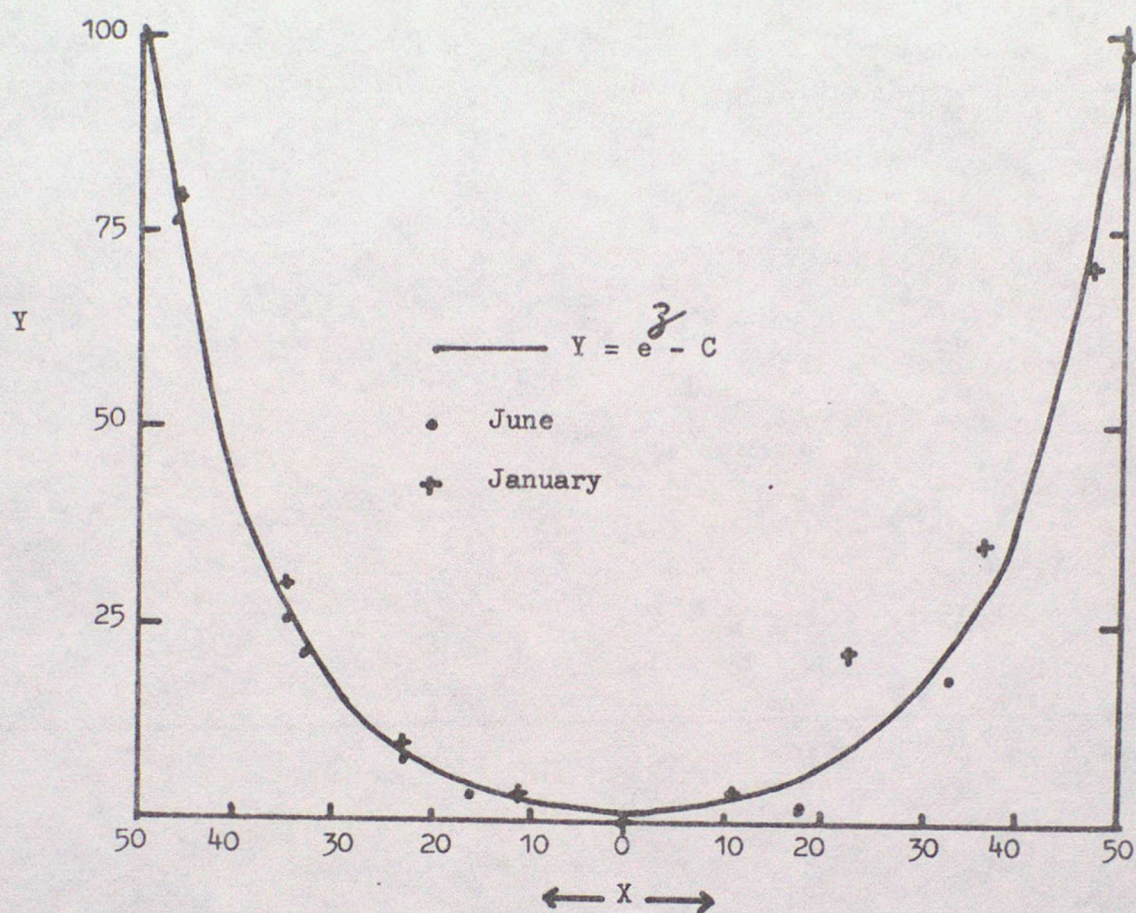


Figure 3

LOSS OF DIFFUSE RADIATION FOR SHELTERBELTS
AT GIVEN DISTANCES AND POROSITIES

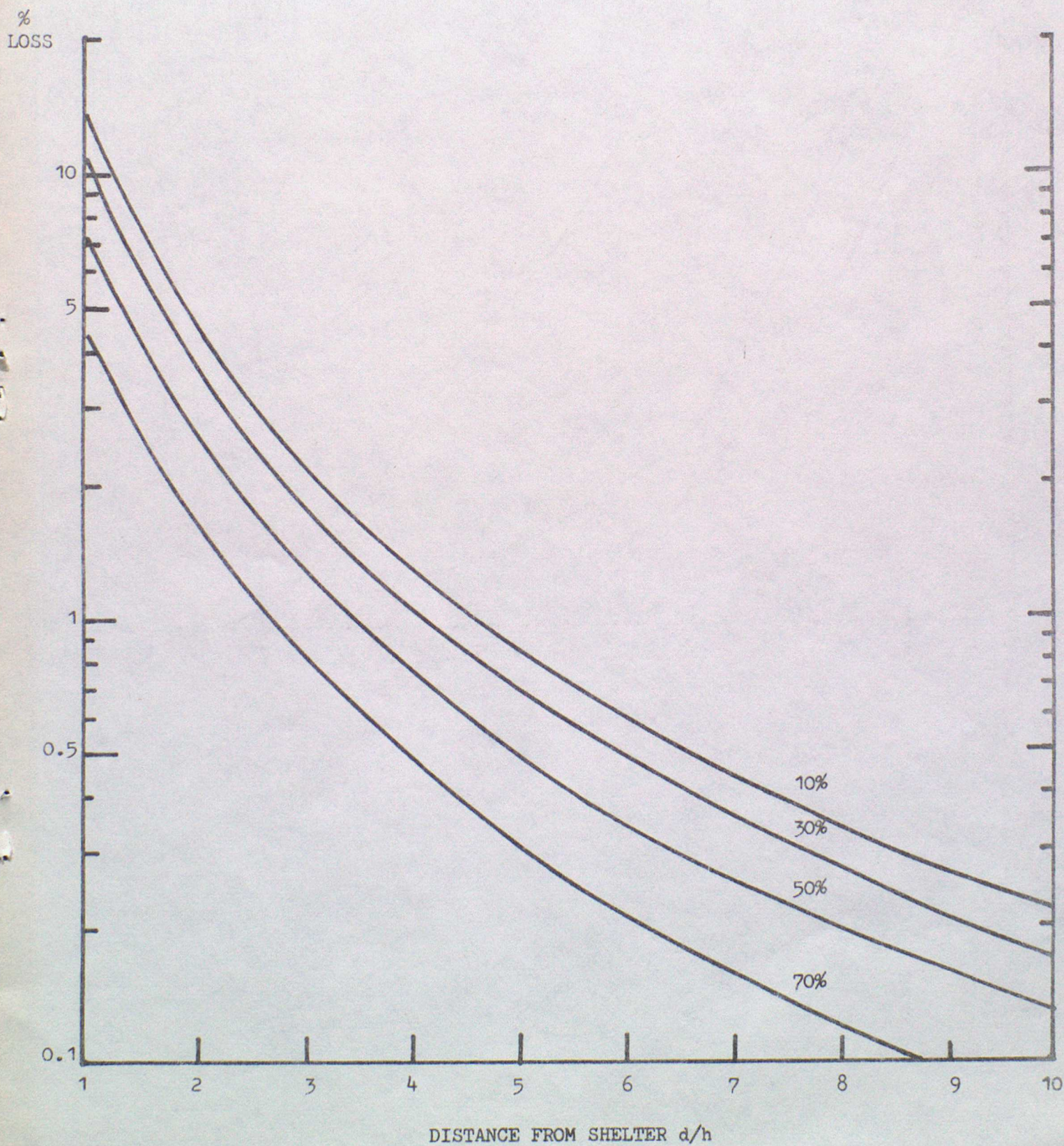


Figure 4

PERCENTAGE LOSS OF RADIATION IN JANUARY FROM
OPTICALLY OPAQUE SHELTER PROTECTING 3 SIDES
OF A GLASSHOUSE. LAT 51°N

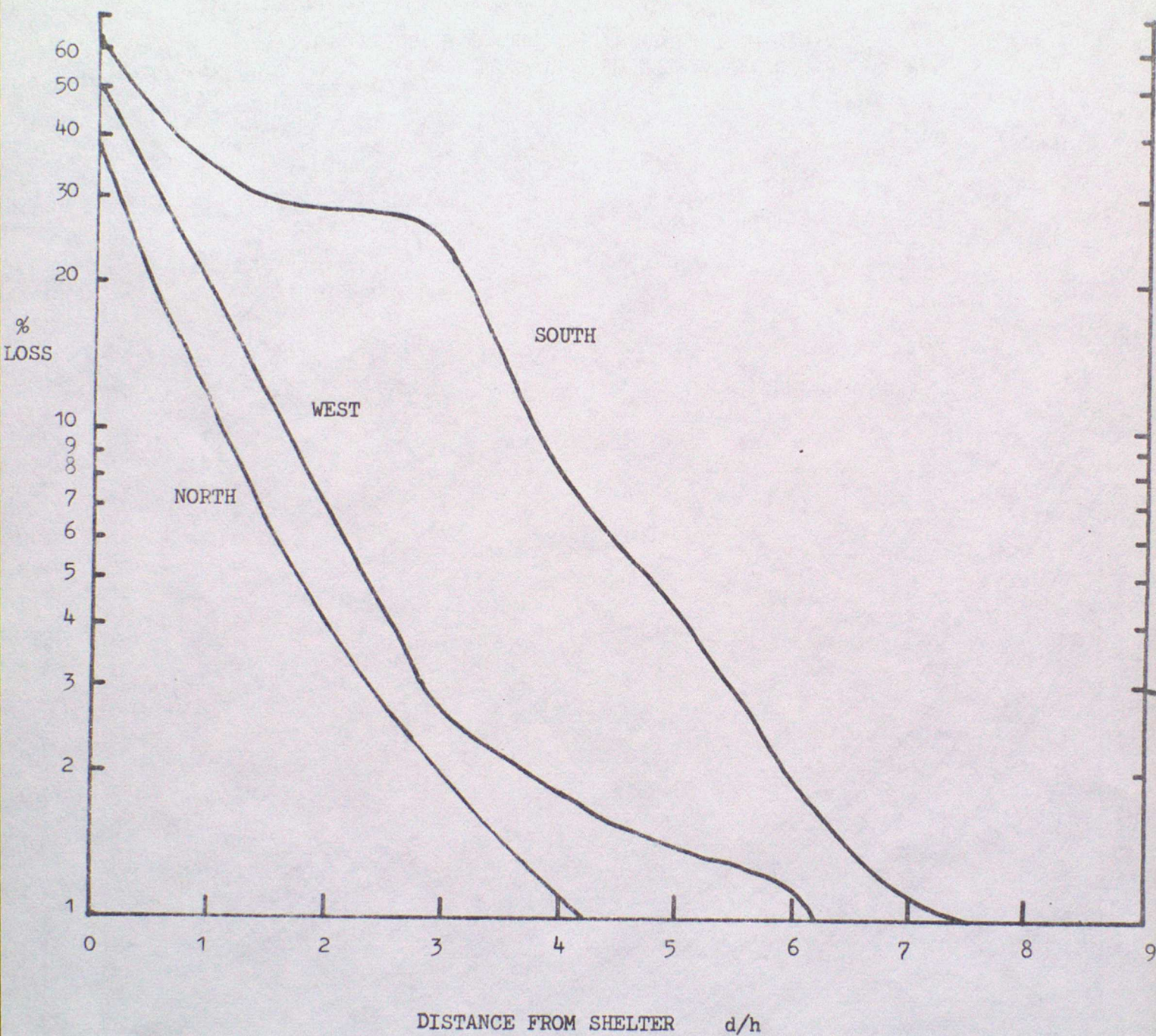
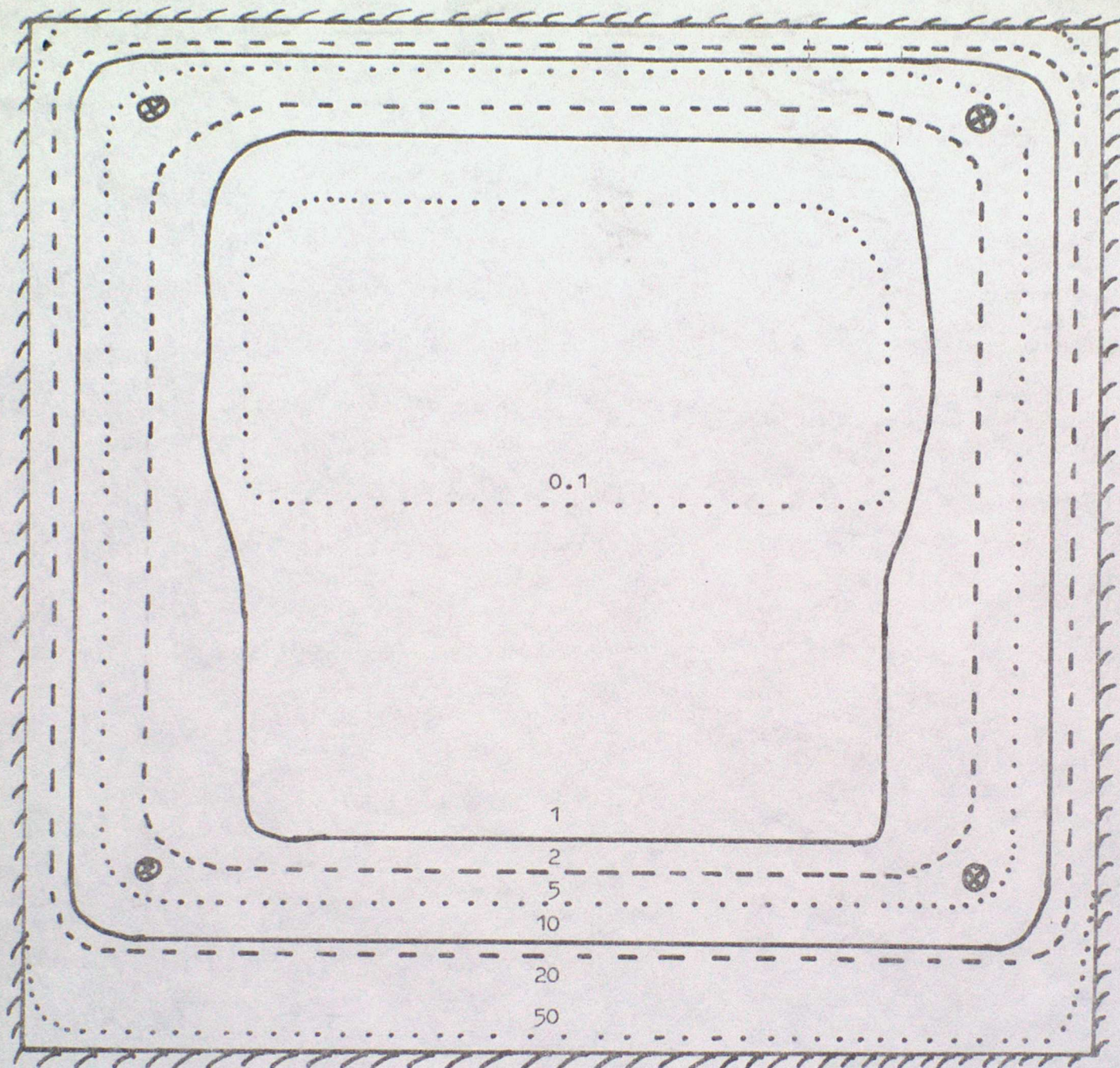


FIGURE 5



PERCENTAGE LOSS OF RADIATION IN JANUARY FROM AN OPTICALLY OPAQUE SHELTERBELT.
4 m HIGH. LAT 51° N

10 m

 CORNERS OF 1 HA BLOCK

APPENDIX I - MINIMUM PERCENTAGE DIFFUSE RADIATION

	J	F	M	A	M	J	J	A	S	O	N	D
Aberporth	73	58	53	53	51	49	55	53	52	57	66	70
Aldergrove	67	60	57	57	59	56	61	64	58	61	60	68
Cambridge	68	62	57	61	55	55	59	59	54	58	64	69
E Hampstead	70	67	56	60	57	52	55	55	55	58	56	67
Eskdalemuir	67	59	60	58	61	58	61	61	62	60	61	63
Jersey	67	57	49	48	47	41	45	48	47	49	65	65
Kew	69	59	55	56	57	51	55	56	54	55	63	68
Lerwick	78	61	61	57	58	56	66	61	63	63	72	79
London WC	70	60	55	58	57	48	55	55	52	55	62	69